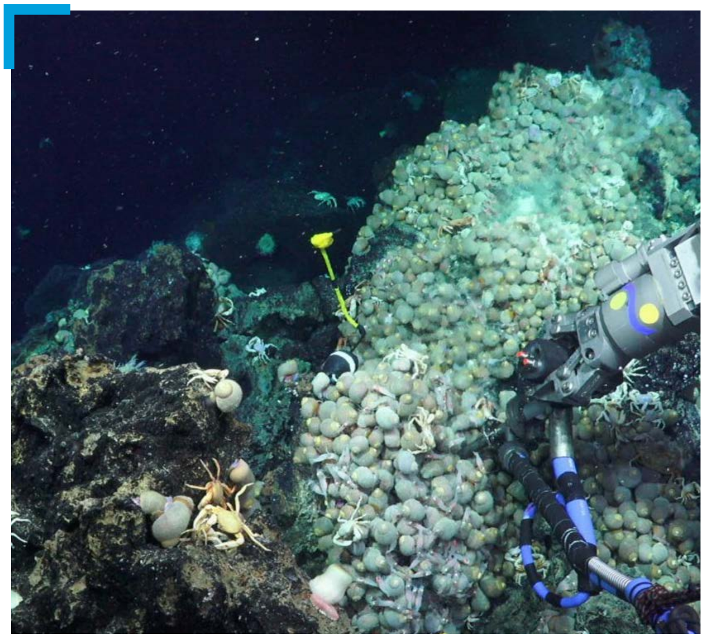
Chemosynthesis

Chemosynthesis is the synthesis of organic compounds by bacteria or other living organisms using energy derived from reactions involving inorganic chemicals, typically in the absence of sunlight.

The majority of life on the planet is based in a food chain which revolves around sunlight, as plants make food via photosynthesis. In the deep ocean, however, there is no light, so there are no plants. Instead of sunlight being the primary form of energy, chemical energy is produced by a process called chemosynthesis. Places with chemosynthetic organisms, such as hydrothermal vents, can become incredible oases of life in the deep sea.

Chemosynthesis was first identified in 1977 when a team of scientists on an ocean research expedition near the Galápagos Islands off the coast of Ecuador found hot vents on the ocean floor spewing a chemical soup of hot fluid. Surrounding these hydrothermal vents was a community of several new animal species—thriving despite living in total darkness with no access to sunlight! These incredible communities have since been found at spreading centers and subduction zones around the globe.



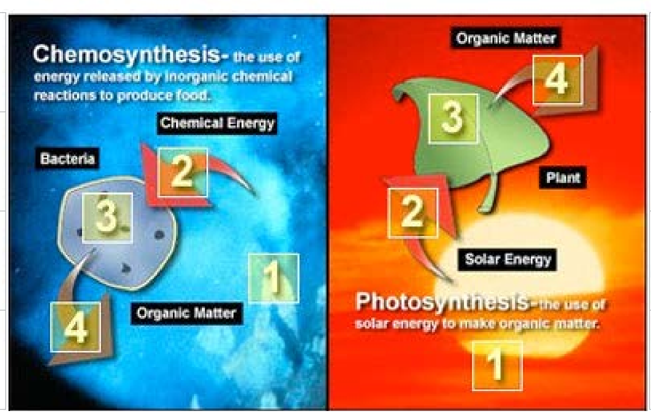
ROV *SuBastian* uses a fluid sampler to assess a low temperature vent at Alice Springs in the Mariana Back-Arc. A black and white 'robo snail' probe (center) measures the temperatures supporting this large group of vent snails. *Image courtesy of the Schmidt Ocean Institute.*

Chemosynthesis vs. Photosynthesis

This diagram compares examples of these two processes—chemosynthesis in a seafloor hydrothermal vent bacterium and photosynthesis in a terrestrial plant.

Figure adapted from NOAA Ocean Exploration.

Hot water gushing from hydro-thermal vents is saturated with dissolved chemicals.	1	1	The Sun gives off energy in the form of light.
Microbes, like bacteria and archaea, absorb hydrogen sulfide and carbon dioxide from vent water and oxygen from seawater.	2	2	Plants absorb sunlight, and take up water from the soil and carbon dioxide from the air.
The microbes use energy released by oxidizing sulfur to make organic molecules.	3	3	The plants use solar energy to make organic molecules.
The microbes grow and reproduce, and are eaten or hosted as internal symbionts by other animals.	4	4	The plants grow and reproduce, and are eaten or hosted as internal symbionts by animals.



Chemosynthesis

Photosynthesis

All photosynthetic organisms use solar energy to turn carbon dioxide (CO_2) and water (H_2O) into sugar ($C_6H_{12}O_6$) and oxygen (O_2). There is only one formula for photosynthesis:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

Carbon dioxide + Water → Sugar + Oxygen

Photosynthesis occurs in plants and some bacteria, wherever there is sufficient sunlight—on land, in shallow water, even inside and below clear ice.

Chemosynthesis (at hydrothermal vents)

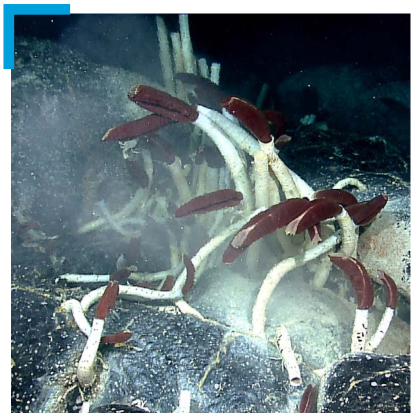
Chemosynthetic organisms use the energy released by chemical reactions to make sugars, or food. Hydrogen sulfide is abundant in the extremely hot water erupting from hydrothermal vents. Hydrothermal vent bacteria **oxidize** hydrogen sulfide (H_2S), add carbon dioxide (CO_2) and oxygen (O_2) and produce sugar (CH_2O), sulfur (S), and water (H_2O):

$$CO_2 + 4H_2S + O_2 \rightarrow CH_2O + 4S + 3H_2O$$

Carbon dioxide + Hydrogen Suifide + Oxygen → Sugar + Sulfur + Water

OXIDIZE: To undergo or cause to undergo a reaction in which electrons are lost to another species.

This is one example of a chemosynthetic pathway. Scientists have also found chemosynthetic bacterial communities in hot springs on land, and in cold seeps, on sunken ships, and even on decomposing whale carcasses on the seafloor. The chemosynthetic microbes within these environments also use chemical energy to create sugar, but different species use different pathways. For example, bacteria found at cold seeps, where hydrocarbons (primarily methane, CH4) bubble from the seafloor, oxidize methane during chemosynthesis. Scientists are still working to better understand the biochemical pathways in chemosynthetic communities.



Riftia tubeworms colonize diffuse vent habitats between broken pieces of lava. *Image courtesy of the NOAA Ocean Exploration.*

Why Is Chemosynthesis Important?

In an unlit world without access to the Sun's energy, chemosynthesis provides the basis for the development of rich, diverse communities. Chemosynthetic deep-sea bacteria form the base of a food web that includes a significant variety of marine life including shrimp, tubeworms, clams, crabs, fish, and octopods, just to name a few.

ADDITIONAL RESOURCES

FOR MORE ON HYDROTHERMAL VENTS
https://www.whoi.edu/feature/history-hydrothermal-vents/impacts/view.html

FOR MORE ON CHEMOSYNTHETIC COMMUNITIES
https://oceanexplorer.noaa.gov/okeanos/explorations/ex1711/logs/photolog/welcome.html#cbpi=/okeanos/ explorations/ex1711/dailyupdates/media/video/chemosynthesis/chemosynthesis.html

Chemosynthesis (photo 1): https://schmidtocean.org/collection/searching-life-mariana-back-arc/
Chemosynthesis/Photosynthesis Diagram: https://oceanexplorer.noaa.gov/edu/learning/5_chemosynthesis/activities/chemovsphoto.html
Tube Worms (photo 2): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1103/logs/july24/media/tubeworms-hires.jpg

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